A Case Study of Integrating the Taguchi Loss Function and Topsis Method to Select an Optimal Supplier in a Manufacturing Industry

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***Abstract*—**Supplier selection is a important issue in supply chain management. The manufacturer's spends more than 60% of its total sales in on purchased items. In today's highly competitive global operating environment, it is impossible to produce low-cost, high quality products successfully without satisfactory suppliers. Therefore selecting a supplier is a tremendous importance. Decision maker always consider many criteria in supplier selection problem to find their best supplier. Hence supplier selection problem belong to Multi Criteria Decision Making (MCDM).There are many tools to select a supplier in a manufacturing industry. This paper presents integration the taguchi loss function and topsis method to select an optimal supplier in supply chain management.

***Keywords*—**NIS, PIS, SCM, Topsis, Taguchi Loss Function

***Abbreviations*—**Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Negative Ideal Solution (NIS), Supply Chain Management (SCM), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

I. Introduction

IN effective supply chain management, correct vendor evaluation plays the most important role in formulating sub-contracting strategies. Correct vendor evaluation helps an organization, directly and indirectly, to improve product quality, and reduce production costs and lead times for new product introduction [Pal & Kumar, 2010]. Supplier selection is the first step of the activities in the product realization process starting from the purchasing of material till to the end of delivering the products [Elanchezhian et al., 2010]. Supplier selection is evaluated as a critical factor for the companies desiring to be successful in nowadays competition conditions [Sanjay Sharma & Srinivasan Balan, 2012]. Supplier selection is a Multi-criterion problem which includes both qualitative and quantitative factors (criteria). A trade-off between these tangible and intangible factors is essential in selecting the best supplier [Farzad Tahriri et al., 2008]. Supplier selection is a fundamental issue in SCM because most of the companies spend more cost on raw materials. Therefore supplier selection places a major role in SCM [Chen et al., 2006].

II. Literature Survey

Supply chain management is one of the most important concepts in recent decades. The globalization and the competitiveness have motivated higher attention to SCM process. SCM, which integrates suppliers, manufactures, distributors and customers is diffused in the firm in order to improve flexibility, cost, quality and delivery performance [Wacker, 1996]. Supplier selection may be single most important phase of the purchasing process [Edward J. Hay, 1990]. The objective of this stage is to find the optimal supplier [Robert L Nydic, 1992]. So, the firm must considered multi criteria in their attempts to distinguish between items offered by potential suppliers [Ed Timmerman, 1986]. It is the important job for decision makers to select proper suppliers in their supplier chain management. They need to use some criteria to evaluate their alternative and find which one is the best for them. Hence the

supplier selection problem belongs to the MCDM [Monezka & Trecha, 1998].

Weber, Current & Benton (1990) paid their attention to survey how to select the criteria in this problem such as like the product quality offering price, delivery lead time, service satisfaction, warranty degree, experience and financial stability. According to Kameshwaran & Narahari (2003), upgrading to E-Procurment from traditional procurement helps the organization reduce operational cost, shorten the order fulfilment, cycle time, lower inventory level and create the collaborative partnership.

Luitzen de Boer et al., (2001) also analyzed the literature from the perspective of supplier selection methodologies and proposed an extension to the research done by Weber et al, (1991). Several conflicting quantitative and qualitative factors or criteria like cost, quality, delivery etc., affect the supplier selection problem [Amid et al., 2009]. Therefore it is a MCDM problem. Several methods such as Analytic Hierarchy Process [Narasimhan, 1983; Barbarosoglu & Yazgac, 1997], Analytic Network Process [Sarkis & Talluri, 2000], Linear weighting methods [Timmerman, 1986; Thompson, 1990], Total cost approach [Smytka & Clemens, 1993; Monezka & Trecha, 1998], Mathematical programming techniques [Buffa & Jackson, 1983; Chaudhry et al., 1993] have helped the decision makers to deal with supplier selection process.

III. The Proposed Method

3.1. Projected Integrative Supplier Selection Representation

Figure 1 illustrates the schematic explanation of the Integrative supplier selection representation. The criteria for selecting a supplier are quality, on time service, price and service. By using these criteria the losses for each supplier is calculated. Then determine the taguchi loss function. The weight of the each criteria are assumed by different expert opinion. With the help of weightage given ranking of supplier is done by topsis method [Sanjay Sharma & Srinivasan Balan, 2012].

3.2. Taguchi Loss Function

The quality loss function developed by Genichi Taguchi. In traditional system, if a product measurement falls within a specification limit, the product is accepted: otherwise, product is rejected.

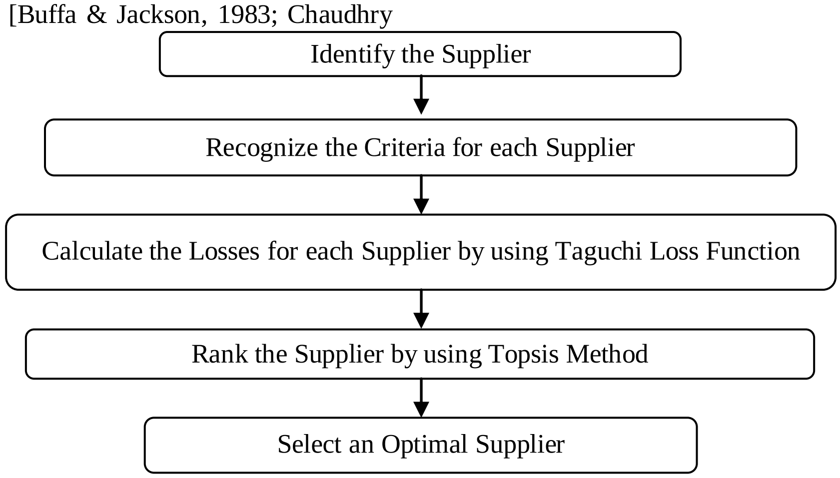

Figure 1 – Integrative Supplier Selection Representation

The taguchi loss function will occur only when the product is of unacceptable quality [Wei-Ning Pi & Chinyao Low, 2005].

The objective of taguchi loss function is to minimize the variation from the target on both sides of the specification. The loss function is measured by quadratic function. Genichi Taguchi considers three characteristics, nominal-the best, smaller-the-better, and larger-the-better [Wei-Ning Pi & Chinyao Low, 2006].

In nominal-the best, the target will be at the center and the variation will be allowed in both the direction. This is also called as two-sided specification limit. The loss function is formulated as [Wei-Ning Pi & Chinyao Low, 2005].

$$L(y) = K(y-m)^2$$

L(y) is the loss associated with particular quality characteristics, K is the loss coefficient, y is the target value. m is the nominal value. K is formulated as

$$K = A/\Delta^2$$

A is the average quality loss. Δ is the tolerance limit.

The other two function are smaller-the better and larger-the better called as one- sided minimum-specification limit and one- sided maximum-specification limit respectively [Wei-Ning Pi & Chinyao Low, 2005]. This is formulated as

$$L(y) = Ky^2$$
$$L(y) = K/y^2$$

3.3. Topsis Method

Topsis method was first developed by Yoon & Hwang. It is based on the concept that the optimal alternative should have the shortest distance from Positive Ideal Solution (PIS) and the farthest distance from Negative Ideal Solution (NIS) [Sarojini Jajimoggala et al., 2011]. There are various step to adopt topsis process that are listed below [Farzad Tahriri et al., 2008].

Step 1: Developing decision matrix for ranking.

Step 2: Calculate the normalized decision matrix. The S_{ij} is calculated as

$$S_{ij} = P_{ij} / \sqrt{\sum (P_{ij}^2)}$$

S_{ij} represents normalized value.

Step 3: Construct weighted normalized decision matrix. The V_{ij} is calculated as $V_{ij} = W_{ij}.\ S_{ij}$

$W_{ij.}$ Is the weight of the criteria

V_{ij} denotes weighted normalized value.

Step 4: Determine the PIS and NIS respectively.

Step 5: Calculate separation measure E_i^+. The E_i^+ is calculated as $E_i^+ = [\sum(v_i^+ - v_{ij})^2]^{1/2}$

Step 6: calculate separation measure E_i^-. The E_i^- is calculated as $E_i^- = [\sum(v_i^- - v_{ij})^2]^{1/2}$

Step 7: find the separation measures and relative closeness coefficient. The H_i is calculated as $H_i = E_i^+ /(E_i^+ + E_j^-)$

The below data is taken from manufacturing sector, which is a leader in production and marketing of power and distribution transformers.

Step 1**:** Decision variables for selecting supplier. The decision variables and values are shown in table 1.

Table 1 – Decision Variables and Values

	Target Value	Range	Specification Limit
Quality	0%	0-3%	3%
On Time Delivery	0	0-7 days	7 days
Price	Lowest	0-15%	15%
Service	100%	100-90%	90%

Step 2: Characteristic and relative value of supplier. The value & relative value of supplier with respective to each criteria is shown in table 2.

Table 2 – Value & Relative Value of Supplier

	C1		C2		C3		C4	
S	**V**	**RV**	**V**	**RV**	**V**	**RV**	**V**	**RV**
A	1.80	1.80	6	6	110	10	99	99
B	1.50	1.50	4	4	108	8	97	97
C	1.00	1.00	5	5	100	0	98	98
D	1.40	1.40	2	2	114	14	93	93
E	2.50	2.50	3	3	112	12	95	95
F	1.80	1.80	1	1	109	9	94	94
G	1.20	1.20	4	4	103	3	96	96
H	2.80	2.80	6	6	107	7	92	92
I	2.90	2.90	3	3	105	5	91	91
J	1.50	1.50	5	5	103	3	93	93

C1 - Quality (%)
C2 - On time delivery (days)
C3 - Price (Thousand/ton)
C4 - Service
S - Service
V - Value
RV - Relative Value

Step 3: Characteristic using taguchi loss function. The loss value of each supplier is shown in table 3.

K value for the quality, on time delivery, price and service are 111111.11, 2.408, 4444.44, 9.876 respectively. For quality, on time delivery, price smaller-the better formula are to be used. For service larger-the better formula is to be used.

Table 3 – Loss Value of Each Criteria

Supplier	Quality	On Time Delivery	Price	Service
A	35.99	73.46	44.44	10.07
B	24.99	32.65	28.44	10.49
C	11.11	51.02	0	10.28
D	21.77	8.16	87.11	11.41
E	69.44	18.36	64	10.94
F	35.99	2.04	35.99	11.17
G	15.99	32.65	3.99	10.71
H	87.11	73.46	21.77	11.66
I	93.44	18.36	11.11	11.92
J	24.99	51.02	3.99	11.41

Step 4: Weight of the criteria

Weight of the each criteria is assumed by the procurement manager of the manufacturing company. According to the weight of the criteria supplier are to be ranked using topsis method. Weight of the criteria is shown in table 4.

Table 4 – Weight of the Criteria

Criteria	Weight
Quality (C1)	0.3
Delivery time (C2)	0.1
Price (C3)	0.14
Service (C4)	0.12

Step 5: Developing decision matrix. Developing decision matrix for each criteria is shown in table 5.

Table 5 – Decision Matrix Value for Each Criteria

	C1	C2	C3	C4
A	35.99	73.46	44.44	10.07
B	24.99	35.65	28.44	10.49
C	11.11	51.02	0	10.28
D	21.77	8.16	87.11	11.41
E	69.44	18.36	64.00	10.94
F	35.99	2.04	35.99	11.17
G	15.99	32.65	3.99	10.71
H	87.11	73.46	21.77	11.66
I	93.44	18.36	11.11	11.92
J	24.99	51.02	3.99	11.41

Step 6: Calculating the normalized decision matrix. The normalized decision matrix of each criteria is shown in table 6.

$$S_{ij} = P_{ij} / \sqrt{\sum (P_{ij}^2)}$$

Table 6 – The Normalized Decision Matrix of Each Criteria

	C1	C2	C3	C4
A	0.22	0.53	0.34	0.28
B	0.15	0.25	0.22	0.30
C	0.06	0.36	0	029
D	0.135	0.05	0.68	0.32
E	0.43	0.13	0.49	0.31
F	0.22	0.01	0.28	0.32
G	0.09	0.23	0.03	0.30
H	0.54	0.53	017	0.33
I	0.58	0.13	0.08	0.34
J	0.15	0.36	0.03	0.32

Step 7: Calculating the weighted normalized decision matrix. The weighted normalized decision matrix of each criteria is shown table 7.

$$V_{ij} = W_{ij}.\ S_{ij}$$

Table 7 – Weighted Normalized Decision Matrix of Each Criteria

	C1	C2	C3	C4
A	0.06	0.053	0.0476	0.033
B	0.04	0.025	0.03	0.036
C	0.01	0.036	0	0.034
D	0.04	0.005	0.09	0.038
E	0.12	0.013	0.06	0.037
F	0.06	0.001	0.03	0.038
G	0.02	0.023	0.004	0.036
H	0.16	0.053	0.02	0.039
I	0.17	0.013	0.001	0.040
J	0.04	0.036	0.004	0.038

Step 8: Determine the PIS and NIS.

$V^+ = [0.17, 0.053, 0.09, 0.04]$, .$V^- = [0.01, 0.001, 0, 0.033]$

Step 9: Calculating separation measure E_i^+**.** E_i^+ values are shown in table 8.

$$E_i^+ = [\sum(v_i^+ - v_{ij})^2]^{1/2}$$

Table 8 – E_i^+ Values

Supplier	Ei+
A	0.118
B	0.145
C	0.184
D	0.138
E	0.070
F	0.135
G	0.176
H	0.070
I	0.089
J	0.1566

Step 10**:** Calculating separation measure E_i^-. E_i^- value is shown in Table 9.

$$E_i^- = [\sum(v_i^- - v_{ij})^2]^{1/2}$$

Table 9 – E_i^- Values

Supplier	E_i^-
A	0.086
B	0.048
C	0.35
D	0.095
E	0.125
F	0.333
G	0.024
H	0.160
I	0.160
J	0.046

Step 11: separation measures and relative closeness coefficient. Supplier ranking is shown in table 10.

$$H_i = E_i^+ / (E_i^+ + E_j^-)$$

Table 10 – Supplier Ranking

Supplier	Closeness Coefficient	Ranking of Supplier
A	0.017	6
B	0.0092	8
C	0.0076	9
D	0.022	5
E	0.024	4
F	0.155	1
G	0.0048	10
H	0.0368	3
I	0.0398	2
J	0.0093	7

IV. CONCLUSION

Thus paper proposes an integrative approach to solve the supplier selection using taguchi loss function and topsis method.. Finally the numerical example has been evaluated and concluded that supplier ‘F’ is an optimal supplier in a manufacturing industry. The supplier selection is based on quality, on time delivery, price and service. For a manufacturing industry, multi-criteria is a important role.

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